SOLAR RESEARCH NOTES

Sacramento Peak Observatory

Sunspot, New Mexico

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PHOTOMETRY OF SOLAR FLARES

by

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The present article is presented as a continuation of the work of compiling a catalogue of photometric curves of flares, and as an investigation of the role of various factors influencing the obtained curves. The first catalogue, which included flares of importance 2 and larger, observed in 1957, is contained in [1]. In the present work are included photometric curves of 4 flares (> 2) observed in 1957 and 10 flares of importance > 2 observed in 1958. We should mention that sometimes we had to use old photographic plates, with the result that part of the material was found to be fogged, so that its measurement was rather difficult. From the 10 flares of 1958 subjected to photometric processing, two flares were observed at the edge of the solar disk. In 6 cases photographs began 1 - 2 min. after the appearance of the flare, and in 4 cases the beginning of the flare was not photographed since, for one reason or another, surveys were started only after the flares were observed.

The observations were carried out on the "outside-of-eclipse" coronograph KG-1, with an interference-polarization filter centered on H_α and fulfilling the necessary conditions (speed of the survey, exposure time, standardization, etc.) described in [1]. In May 1958 a wide-angle GOI IF-44 filter with band-pass width of 0.35 A was mounted on the coronograph. The processing of the flares was carried out on the same instruments and by the same methods as earlier [1]. In Table 1 is given information on the flares investigated: date of the survey, time of observations, importance, coordinates of flares, observing conditions, name of observer. Starting and ending times of observations (as is true of all times on graphs) are given in Moscow time (U.T. + 3^h).

The underlined times designate actual beginning and ending times of flares.

In the table, under heading "Observer" letter G indicates that the observations were done by S. C. Gopacyuk, Ts - T. T. Tsap, SH - E. F. Shaposhnikova, O - M.B. Ogir, S. - H. E. Steshenko and A. - S. I. Abramenko.

DISCRIPTIONS OF INDIVIDUAL FLARES

Descriptions are given only for those flares in which some interesting peculiarity was discovered.

10 June 1958. Flare consisted of a series of bright parts. At approximately 13^h extensive broadening of knot 5 began, and it moved north-east toward the center of the flare.

11 July 1958. In the process of flaring, the knots of the flare expanded and neighboring flocculi grew fainter.

12 July 1958. Appeared not far from the solar limb. From 10^h57^m to 11^h03^m flare was accompanied by sprays. At first, knot 1 flared and subsided, and then knot 2 behaved in a similar manner.

16 Aug. 1958. Around 8^h knot 2' detached itself from knot 2, increased in size, and moved toward spot b. Later, knot 2' gradually moved south-east with spot b. Knot 2 moved in the same direction. Knot 3 first moved north-west in the direction of the spot, and then moved to the south-east. At 7^h43^m several faint points remained in the place. At 7^h51^m knot 3 again became brighter.

22 Aug. 1958. The knots of the flare were situated along a filament. Motion was observed in knot 3. At its maximum brightness the flare hid both spots.

CURVES OF GROWTH OF FLARES

On Fig. 1 and 2 are presented photographs of the flares, and on Fig. 3 - 16 are given drawings of the development of intensity and area for the brightest parts of chromospheric flares. The intensity curve for each flare is given above the area curve. Along the abscissa axis is set the time, common for both drawings; along the ordinate axes are given the scale of intensities to the left, and the scale of areas to the right. Intensities of flares are expressed in units of intensity of undisturbed regions adjacent to the flare (I_{qs})* at the same distance from the center of the disk and in the same band-pass of the filter, centered on H_α. Areas of flares - S - are expressed in units of $0.5 \cdot 10^{-6}$ S_D (area of the disk). The small fluctuations in brightness obtained for the measured points were not considered significant.

On the sketches accompanying the graphs of flares we use the conventional means of designating 1) center of the flare - solid black areas, 2) flocculi - shaded areas, 3) spots - circles enclosing dots, and 4) filaments - plain outlines.

Because of the fact that further extensions of photometry of flares are planned, using data of other observatories, we carried out comparisons of the results obtained in surveys of photographs on various instruments using various interference-polarization filters

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*qs - quiet sun

(IPF). In Fig. 17-22 are presented comparisons of photometric curves obtained as a result of measurement of photographs of a single flare taken with various instruments: on the KG-1 coronagraph, the AFR-2 chromospheric telescope installed in Simeiz, and the AFR-2 of the Central Astronomical Observatory, Akademiya Nauk, USSR. Films taken at the CAO, AN, USSR were kindly placed at our disposal by E. A. Gurtovenko. The comparison shows that results of measurements are much closer to each other with instruments of the same type, than with instruments that are quite different from each other.

We will examine various factors influencing both the estimation of flare brightness and the results of the comparison. The brightest places on sufficiently clearly outlined knots of a flare are selected for photometric measurement. The complexity of choosing the knot in the flare and the particular place of measurement of brightness on the undisturbed disk rather strongly influences the results. For example, in the case of the KG-1 coronograph there is room on the plates for only part (12') of the image of the solar disk on the film, making the search for an undisturbed spot on the solar disk difficult. This was one of the reasons for differences in the results obtained.

We could have expected that the choice of slit-width would influence the results. However, measurements (carried out, it is true, only for one flare) showed that identical results are obtained when there is a change in the area of the slit within the limits of the dimensions of the chosen section of the knot in the flare. (The knot must have sufficiently uniform brightness throughout - a condition which we always try to satisfy through choice of the measured portion.) The slit selected was, to be sure, far larger than the grain of the emulsion of the film (Fig. 23). It is pertinent to note, here, that the granularity of the film used at present for the chromospheric flare patrol is very great, thus unfavorably influencing the results obtained.

Different resolving power of the instruments can also lead to differences in results of photometric measurements.

Indeed, if we compare results obtained with different instruments or with different diaphragming of objectives on identical instruments, photometry gives different values of brightness for bright components that are resolved with one instrument and are blurred with others. Thus, in using the AFR-2 chromospheric telescope details larger than 2", 3-2", 5 are resolved, while the coronograph KG-1, without diaphragming, can resolve details on the order of 1". It is necessary to take this circumstance into consideration, since the compilation of the catalogue was planned in collaboration with foreign observatories, which do not have the sort of instruments or filters provided for the group of observatories carrying out solar flare patrols in USSR. Different results will be obtained, also, when filters with different band-pass widths are used. According to our calculations,

the flare brightness, in units of adjacent undisturbed disk, proves to be roughly 20% greater with the use of a filter with a band-pass width of 0.5 A than with the use of the IPF with a band-pass width of 0.7 A.

We should keep in mind that the profile of line H_α in flares does not always have the form of a humped curve. Studies of spectra of flares obtained on the BST showed [2] that these curves are often bifurcated.

Band displacement, even up to 0.2-0.3 A (i.e., so that the fine structure of the chromosphere, - chromospheric spicules - become clearly visible), due to inaccuracies in thermostatic control or due to the inclination of the filter, results in a change in the amount of energy transmitted by the filter. This change varies for different forms of curves of flare profiles. We have calculated the change in transmission of filters with band-widths of 0.6 A by band displacement of 0.3 A for two different profiles of flares (July 16, 1957 and Sept. 3, 1957) drawn up by A. N. Kobal from spectra obtained on the BST (Fig. 24 and 25). The flare brightness decreased by 15% in one case and by 4 5% in the other.

The secondary maxima of transmission of the filter have a special significance. They can be various distances from the center of line H_α and have various values in different filters. In Fig. 26 - 29 are given transmission curves of the filters: Fig. 26 - the wide-angle GOI IF-44 filter, after removal of the last calcite plate and adjustment of the filter in the observatory, Fig. 27 - the Kiev IF-46 filter [3], Fig. 28 - the IF-46 filter installed at Simeis, and Fig. 29 - the IPF, built by A. B. Gilvarg and A. B. Severny, at the Crimean Ast. Obs. Akad. Nauk, USSR [4].

In Table 2 are given data on the secondary maxima of these filters. As an example, - emphasizing the role of the secondary maxima of filter transmission in the study of solar flares, - the following simple calculations are feasible. Let the filter transmit 5% of the light through the secondary maxima and be 0.8 A distant from the center of H_α. Then it transmits 11% of the light from the undisturbed disk. (The profile of H_α is determined according to the spectra obtained on the BST). But if the maximum of emission of the flare coincides with the secondary maximum of the transmission of the filter, and if its brightness (as is often the case) is 7 times greater than the brightness of the disk in the center of H_α, then through the secondary maximum, alone, will pass 7 X 5 = 35% of the light, i.e., nearly half of all the light transmitted from the non-disturbed disk in the main transmission band of the filter. In Fig. 30 - 32 it is obvious that the role of secondary maxima can be completely different in the case of different forms of emission profiles of a flare in H_α. In Fig. 33, 34 it is apparent that, for a single flare profile, different filters, - although of the same type, - transmit different amounts of light. The brightness of a flare determined by means of one filter will be 19% greater than the same value determined by means of another. Since the wave-length of the maximum brightness of a flare

changes with time; when different filters are used one can obtain different relationships of brigthness to time, which inadequately indicate the change, with time, of the flow of Hα emission from the flare.

From the foregoing, it follows that photometric curves of the same flare can be somewhat different for different instruments. Apparently, differences of 25 - 35% from the measured values must be considered quite possible. However, since these curves, nevertheless, can be useful for a series of geophysical applications (see, for example [5]), we consider it necessary to continue the work of compiling a catalogue of photometric curves of flares observed at different observatories beyond the time of IGY. The material obtained on instruments of the same type, or on instruments similar to each other, is of the greatest interest for this purpose.

We express our gratitude to H. V. Godovnikovo for his help in the organization of the material.

CAPTIONS

Table 1 - Comments (In order in which they appear)

Observations thru breaks in clouds.

Bad observation conditions.

Observations in breaks in clouds.

Survey taken thru breaks in clouds. Observations were not completed due to solid clouds.

Strong winds.

Observations taken thru cirrus.

Start was missed because of change of film. End not observed - sun set.

Fig. 1. Photographs of investigated flares
Fig. 2. Photographs of investigated flares
Fig. 3. Curves of growth of chromospheric flare June 3, 1957.
Fig. 4. Curves of growth of chromospheric flare June 4, 1957.
Fig. 5. Curves of growth of chromospheric flare July 21, 1957.
Fig. 6. Curves of growth of chromospheric flare July 22, 1957.
Fig. 7. Curves of growth of chromospheric flare June 14, 1958.
Fig. 8 Curves of growth of chromospheric flare June 19, 1958.
Fig. 9. Curves of growth of chromospheric flare July 11, 1958.
Fig.10 Curves of growth of chromospheric flare July 13, 1958.
Fig.11. Curves of growth of chromospheric flare July 15, 1958.
Fig.12. Curves of growth of chromospheric flare Aug. 13, 1958.
Fig.13. Curves of growth of chromospheric flare Aug. 16, 1958.
Fig.14. Curves of growth of chromospheric flare Aug. 22, 1958.
Fig.15. Curves of growth of chromospheric flare Sept.14, 1958.
Fig.16. Curves of growth of chromospheric flare Oct. 14, 1958.
Fig.17. Comparison of photometric curves of flare June 24, 1957 obtained by measurement of films. Dashed lines - KG-1 coronograph, Continuous lines - AFR-2 (Simeiz).
Fig.18. as above July 3, 1957.
Fig.19. as above July 16,1957.
Fig.20. as above Aug. 28, 1957.
Fig.21. as above June 19, 1958.
Fig.22. as above June 28, 1958 Dashed lines AFR-2 (Simeiz). Continuous -(Kiev)
Fig.23. Comparison of brigthness curves for knot No. 1, Aug. 16, 1958 flare, by slit. a. 1.8 X 1.9 mm^2 (continuous lines). b. 1.0 X 1.1 mm^2 (dashed lines)
Fig.24. Profile of flare 16 July 1957 (constructed according to spectrograms obtained on BST).
Fig.25. as above Sept. 3, 1957.
Fig.26. Transmission curve of wide-angle filter GOI IF-44.
Fig.27. Transmission curve of filter IF-46 (Kiev, CAO, AN, USSR)
Fig.28. Transmission curve of filter IF-46 (Simeiz).

CATIONS (Contd)

Table 2

Filter	Band-pass width, A	Distance of secondary maximum from center of band A	Intensity of secondary maxima, %

Fig.29. Curves of transmission and secondary maxima of Gilbarg and Severny filter (due to over-exposures it was impossible to construct reliable curves of transmission).

Fig.30. Role of the secondary maximum of transmission of the IT-46 filter (Simeiz) for the case of flare of July 16, 1957. 1. Flare profile. 2. Profile of non-disturbed H_α. 3. Transmission curve of filter. 4. Distribution of energy transmitted by the filter for the quiet sun. 5. Distribution of energy transmitted by the filter for [illegible]

Fig.31. as above July 16, 1957 (Designation of curves as in Fig. 30.)

Fig.32. as above Sept. 3, 1957 (Designation of curves as in Fig. 30.)

Fig.33. Transmission of the IT-46 filter (Kiev) for the case of the Flare of July 16, 1957. (Designation of curves as in Fig. 30.)

Fig.34. as above IT-46 filter (Simeiz).